DECLARATION

I, Tadashi UEDA, a subject of Japan residing at 1994-152, Hazama-cho, Hachioji-shi Tokyo 193-0941 Japan, solemnly and sincerely declare:

That I have thorough knowledge of Japanese and English languages; and

That the attached pages contain a correct translation into English of the specification of the following Japanese Patent Application:

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2000-26139	February 3, 2000

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements are made with the knowledge that willful false statements and the like so made, are punishable by fine or imprisonment, or both, under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 10th day of June, 2005

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JP Application No. 2000-026139

[Name of Document] SPECIFICATION

[Title of the Invention] METHOD FOR MANUFACTURING EXTERNAL FORCE DETECTION SENSOR

[Claims]

[Claim 1] A method for manufacturing an external force detection sensor in which a sensor element is formed by through dry etching of an element substrate, wherein a conductive material is used for an etching stop layer to be used in the dry etching of the element substrate.

[Claim 2] A method for manufacturing an external force detection sensor, comprising the steps of: forming a recessed part on a back face of an element substrate and also forming a membrane on the front face; providing an etching stop layer composed of a conductive material on the top face of the recessed part of the element substrate; joining the back face of the element substrate with a support substrate; and forming a sensor element by dry etching the membrane of the element substrate.

[Claim 3] The method for manufacturing an external force detection sensor according to Claim 2, wherein the recessed part is formed in the central part of the back face of the element substrate.

[Claim 4] A method for manufacturing an external force detection sensor in which a sensor element is formed by through dry etching of an element substrate, wherein an

etching stop layer composed of a conductive material is interposed between the element substrate and a dummy support substrate supporting the element substrate.

[Claim 5] The method for manufacturing an external force detection sensor according to Claim 4, wherein the dummy support substrate and the etching stop layer are removed after a sensor element is formed on the element substrate and thereafter, a support substrate with a recessed part formed therein is arranged on the back face of the element substrate to allow the recessed part of the support substrate to oppose to the sensor element of the element substrate, and the support substrate is joined with the element substrate.

[Claim 6] A method for manufacturing an external force detection sensor, wherein an etching stop layer composed of a conductive material is formed in a set sensor element forming area on the back face side of an element substrate, a support substrate with a recessed part formed therein is arranged on the back face of the element substrate to allow the recessed part of the support substrate to oppose to the etching stop layer of the element substrate, the support substrate is joined with the element substrate and thereafter, the sensor element forming area of the element substrate is worked by through dry etching from the front face to form a sensor element.

[Claim 7] A method for manufacturing an external force detection sensor, wherein an etching stop layer composed of a conductive material is formed on a set sensor element forming area on the back face of an element substrate, a support substrate with a recessed part formed therein is arranged on the back face of the element substrate to allow the recessed part of the support substrate to oppose to the etching stop layer of the element substrate, the support substrate is joined with the element substrate, then, the element substrate is worked so as to be reduced in thickness to a predetermined thickness and thereafter, the sensor element forming area of the element substrate is worked by through dry etching from the front face to form a sensor element.

[Claim 8] A method for manufacturing an external force detection sensor, wherein a set sensor element forming area of an element substrate is processed from both front and back faces to form a membrane, an etching stop layer composed of a conductive material is formed on the back face of the membrane and thereafter, a support substrate is joined with a back face of the element substrate, and the membrane is worked by through dry etching from the front face to form a sensor element.

[Claim 9] The method for manufacturing an external force detection sensor according to Claim 2 or Claim 3 or Claim 5

or Claim 6 or Claim 7 or Claim 8, wherein the element substrate is formed of silicon, the support substrate is formed of a glass material, and the element substrate is anode-coupled to the support substrate.

[Claim 10] The method for manufacturing an external force detection sensor according to any one of Claims 1 to 9, wherein the etching stop layer is formed of a conductive material whose selection ratio that is the ratio of the dry etching rate of the element substrate to the dry etching rate of the etching stop layer is not less than 1.

[Claim 11] The method for manufacturing an external force detection sensor according to any one of Claims 1 to 10, wherein the sensor element is a movable element.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a method for manufacturing an external force detection sensor such as an angular velocity sensor and an acceleration sensor.

[0002]

[Description of the Related Art]

Fig. 6(a) shows a top view of an angular velocity sensor which is an external force detection sensor proposed by the applicant, and Fig. 6(b) shows a sectional view taken along the line A-A in Fig. 6(a). A sensor element 1

constituting the angular velocity sensor shown in Fig. 6(a) and Fig. 6(b) is of predetermined shape in which an element substrate (e.g., a semiconductor substrate such as single-crystal silicon substrate) to be joined with, for example, a glass support substrate 2 is dry etched.

[0003]

As shown in Figs. 6(a) and 6(b), a vibrator 5 is arranged in a floating condition from the support substrate 2 above a surface 2a which is a surface in the direction of X-Y plane of the support substrate 2. The vibrator 5 is configured such that a weight 5b is provided inside a square-shaped frame body 5a. A plurality of (four in an example in Fig. 6) fixed parts 6 are fixed on the support substrate 2 in such a manner as to surround the vibrator 5 with intervals from each other, and the vibrator 5 is supported by each fixed part 6 through each L-shaped support beam (beam) 7 so as to be vibratable in the X-direction and Y-direction.

[0004]

Comb-teeth shaped movable electrodes 10 (10a, 10b) are formed on both right and left sides of the vibrator 5 in the figure outwardly in each horizontal direction (X-direction), and fixed comb-teeth electrodes 11 (11a and 11b) to be meshed with the movable electrodes 10 through clearance are extended inward of fixed parts 12 in the

horizontal direction.

[0005]

A conductive pattern that is not shown in the figure is connected to the fixed comb-teeth electrodes 11a and 11b, and the voltage can be applied to the fixed comb-teeth electrodes 11a and 11b from the outside through the conductive pattern. For example, when the AC voltages different in phase by 180° are applied to the fixed comb-teeth electrodes 11a and 11b through the conductive pattern with the movable electrodes 10a and 10b in the condition of a set fixed voltage (e.g., zero V), electrostatic forces opposite in direction to each other are generated between the movable electrode 10a and the fixed comb-teeth electrode 11a, and between the movable electrode 10b and the fixed comb-teeth electrode 11b, and the vibrator 5 is excitation-vibrated in the X-direction by the electrostatic forces.

[0006]

In addition, movable electrodes 13 (13a and 13b) are extended on the upper and lower sides of the vibrator 5 in the figure outwardly in each longitudinal direction (Y-direction), and fixed electrodes 14 (14a and 14b) opposite to the movable electrodes 13 through a clearance are extended inward of a fixed part 15 in the vertical direction.

[0007]

In the angular velocity sensor (external force detection sensor) of the above-described configuration, the Coriolis force is generated in the Y-direction when the external force detection sensor rotates with the Z-axis orthogonal to the direction of the X-Y plane as the axis of rotation in a condition where the vibrator 5 is excitation-vibrated in the X-direction as described above. The Coriolis force is applied to the vibrator 5, and the vibrator 5 is vibrated in the direction of the Coriolis force. The clearance between the movable electrodes 13 and fixed electrodes 14 is changed by the vibration in the Y-direction of the vibrator 5 due to the Coriolis force, and the electrostatic capacity between the movable electrodes 13 and the fixed electrodes 14 is changed. The magnitude of the angular velocity of the rotation can be detected by detecting the electric signal corresponding to the magnitude of the amplitude vibration in the Y-direction of the vibrator 5 generated by the above-described Corioli's force making use of the change in electrostatic capacity. Thus, the sensor element 1 of the angular velocity sensor shown in Fig. 6 forms a movable element having a movable part such as the vibrator 5 and a support beam 7.

[0008]

Next, an example of the method for manufacturing the

angular velocity sensor shown in Fig. 6 will be briefly described using sectional views shown in Figs. 7(a) to 7(e). For example, as shown in Fig. 7(a), a recessed part 16 is formed on the back face 3b of an element substrate 3 by dry etching technology such as RIE (Reactive Ion Etching) to form, for example, a membrane (diaphragm) 17 with a thickness of 60 to 70μm.

[0009]

Next, as shown in Fig. 7(b), an etching stop layer 18 consisting of silicon oxide is formed on a top face 16a of the recessed part 16 using a film deposition technology such as CVD (Chemical Vapor Deposition).

[0010]

Then, as shown in Fig. 7(c), the support substrate 2 is arranged on the back face 3b of the element substrate 3, the support substrate 2 and the element substrate 3 are heated to high temperature, and high voltage is applied thereto to anode-couple the support substrate 2 to the element substrate 3.

[0011]

Thereafter, the membrane 17 of the support substrate 2 is worked using a photolithography method and the RIE to form a plurality of through parts 20 reaching the etching stop layer 18 from the front face 3a of the element substrate 3 as shown in Fig. 7(d). By the plurality of

through parts 20, the vibrator 5, the support beams 7, the movable electrodes 10, the fixed comb-teeth electrodes 11, the movable electrodes 13, the fixed electrode 14, etc. are configured to form the sensor element 1. In this specification, the dry etching technology for forming the through parts to be passed from the front face to the back face of the substrate is referred to as through dry etching.

[0012]

As described above, after the sensor element 1 is formed, the etching stop layer 18 is removed by means of wet etching using a buffer hydrofluoric acid aqueous solution as shown in Fig. 7(e). In the manner described above, the angular velocity sensor shown in Fig. 6 can be manufactured.

[0013]

[Problems to be Solved by the Invention]

Incidentally, as described above, the etching stop layer 18 formed in manufacturing the external force detection sensor, such as the angular velocity sensor, has been composed of an insulating material such as silicon oxide from the viewpoint of facilitation of forming a layer and simplification of a manufacturing process of the external force detection sensor. However, the inventor has noticed that notches (chips) n are formed on the lower side (i.e., the side on which the etching stop layer 18 is

formed) of a side wall surface of the through parts 20 as shown in Fig. 7(e) since the etching stop layer 18 is formed of the insulating material as described above.

[0014]

This may be considered attributable to the following reason. For example, while the element substrate 3 is being worked by means of through dry etching (during the dry etching) to form the sensor element 1, the etching removal is achieved faster in a part larger in etching removal area such as through parts (etching holes) 20a between the frame body 5a and the weight 5b of the vibrator 5 shown in Fig. 6(a) than in a part smaller in etching removal area such as through parts (etching slots) 20b between the movable electrode 10 and the fixed comb-teeth electrode 11 by the micro-loading effect.

[0015]

As described above, the time required to achieve the etching removal up to the etching stop layer 18 and complete the formation of the through parts 20 after the through dry etching is started is different from each through part 20 by the difference in the etching removal area. Since the through dry etching is continuously performed until the formation of all through parts 20 is completed, some through parts 20 that are continuously exposed to an etching gas are generated although the

etching removal is completed (hereinafter, these through parts are referred to as through parts during the over etching).

[0016]

The etching gas continuously enters such through parts 20 during the over-etching, and the etching stop layer 18 at a bottom part of the through parts 20 are positively (plus) charged by the collision of the positive ion in the etching gas.

[0017]

When the etching is continued even after the etching stop layer 18 is positively charged and the etching gas continuously enters inside the through parts 20, the positive ions in the etching gas go straight toward the etching stop layer 18 inside the through parts 20, but repelled by the positive charge of the etching stop layer 18 immediately before the positive ions reach the etching stop layer 18. In addition, the side wall surface of the through parts 20 is negatively (minus) charged by the collision of the electron in the etching gas, and thus, the positive ions are attracted to the side wall surface of the through parts 20 immediately before they reach the etching stop layer 18, and the course of the positive ions is largely curved. As a result, the positive ions in the etching gas collide with the bottom (on which the etching

stop layer 18 is formed) of the side wall surface of the through part 20 to form the notches n as shown in Fig. 7(e).

[0018]

In addition, since the etching stop layer 18 is formed of the insulating material, it is found that the following problem may occur. The problem is that the heat transfers as indicated by an arrow in Fig. 8(a) when no through parts 20 are completed yet as shown in the figure while the through dry etching is performed to form the through parts 20. For example, the heat generated on the side wall surface of the through parts 20 by the collision of the electrons in the etching gas with the side wall surface is diffused into the membrane 17, and the area to be dry-etched of the membrane 17 or the like is heated to the same temperature almost over the whole area.

[0019]

However, when through parts 20A are generated during the over etching as shown in Fig. 8(b), the temperature of a portion between the through parts 20A during the over etching (for example, a portion indicated by a reference numeral 21 in Fig. 8(b)) is increased. That is, when the electrons in the etching gas collide with the side wall surface of the through part 20A during the over etching to generate the heat, the portion 21 is thermally independent from other areas since the etching stop layer 18 is formed

of the insulating material and the heat conductivity thereof is very low. The heat is accumulated on the side wall surface of the portion 21, and the temperature of the portion 21 is increased higher than the other areas. Thus, the portion 21 becomes easier to be etching-removed than the other areas, the etching removal is excessively achieved as indicated by the solid line while the true etching removal should be achieved to the dimension as indicated by the broken line in Fig. 8(c), raising a problem of the excessive etching that an objective part is not formed to the designed dimension.

[0020]

As described above, the inventor has noticed that the notches n are formed on the etching stop layer 18 of the side wall surface of the through parts 20, the excessive etching is generated, and a condition that the sensor element 1 cannot be formed to the designed dimension with high accuracy since the etching stop layer 18 has been formed of the insulating material. Since the sensor element 1 cannot thus be formed with high dimensional accuracy, for example, there raises a problem that the stable output sensitivity of the external force detection sensor cannot be obtained.

[0021]

The present invention has been made to solve the

above-described problems, and has its object to provide a method for manufacturing an external force detection sensor capable of forming a sensor element to the designed dimension with high accuracy.

[0022]

[Means for Solving the Problems]

To achieve the above-described object, means of the present invention for solving the above-describe problems is the following configuration. That is, in the method for manufacturing an external force detection sensor in a first invention in which a sensor element is formed by effecting through dry etching of an element substrate, the means for solving the above-described problems is of the configuration in which a conductive material is used for an etching stop layer to be used in the dry etching of the element substrate.

[0023]

The method for manufacturing the external force detection sensor in a second invention is characterized by including the steps of: forming a recessed part on a back face of an element substrate and also forming a membrane on the front face; providing an etching stop layer composed of a conductive material on the top face of the recessed part of the element substrate; joining the back face of the element substrate with a support substrate; and forming a

sensor element by dry etching the membrane of the element substrate.

[0024]

The method for manufacturing the external force detection sensor in a third embodiment is characterized in that the recessed part constituting the second invention is formed in the central part of the back face of the element substrate.

[0025]

The method for manufacturing the external force detection sensor in which a sensor element is formed by through dry etching of an element substrate in a fourth invention is characterized in that an etching stop layer composed of a conductive material is interposed between the element substrate and a dummy support substrate supporting the element substrate.

[0026]

The method for manufacturing the external force detection sensor in a fifth invention is characterized in that the configuration of the fourth invention is provided, and that the dummy support substrate and the etching stop layer are removed after a sensor element is formed on the element substrate and thereafter, a support substrate with a recessed part formed therein is arranged on the back face of the element substrate to allow the recessed part of the

support substrate to oppose to the sensor element of the element substrate, and the support substrate is joined with the element substrate.

[0027]

The method for manufacturing the external force detection sensor in a sixth invention is characterized in that an etching stop layer composed of a conductive material is formed in a set sensor element forming area on the back face side of an element substrate, a support substrate with a recessed part formed therein is arranged on the back face of the element substrate to allow the recessed part of the support substrate to oppose to the etching stop layer of the element substrate, the support substrate is joined with the element substrate and thereafter, the sensor element forming area of the element substrate is worked by through dry etching from the front face to form a sensor element.

[0028]

The method for manufacturing the external force detection sensor in a seventh invention is characterized in that an etching stop layer composed of a conductive material is formed on a set sensor element forming area on the back face of an element substrate, a support substrate with a recessed part formed therein is arranged on the back face of the element substrate to allow the recessed part of

the support substrate to oppose to the etching stop layer of the element substrate, the support substrate is joined with the element substrate, then, the element substrate is worked so as to be reduced in thickness to a predetermined thickness and thereafter, the sensor element forming area of the element substrate is worked by through dry etching from the front face to form a sensor element.

[0029]

The method for manufacturing the external force detection sensor in an eighth invention is characterized in that a set sensor element forming area of an element substrate is processed from both front and back faces to form a membrane, an etching stop layer composed of a conductive material is formed on the back face of the membrane and thereafter, a support substrate is joined with a back face of the element substrate, and the membrane is worked by through dry etching from the front face to form a sensor element.

[0030]

The method for manufacturing the external force detection sensor in a ninth invention is characterized in that the element substrate constituting the second or third or fifth or sixth or seventh or eighth invention is formed of a silicon, the support substrate is formed of a glass material, and the element substrate is anode-coupled to the

support substrate.

[0031]

The method for manufacturing method the external force detection sensor in a tenth invention is characterized in that the configuration of any one of the first to ninth inventions is provided, and that the etching stop layer is formed of a conductive material whose selection ratio that is the ratio of the dry etching rate of the element substrate to the dry etching rate of the etching stop layer is not less than 1.

[0032]

The method for manufacturing the external force detection sensor in an eleventh invention is characterized in that the sensor element to constituting any one of the first to tenth inventions is a movable element.

[0033]

In the invention of the above-described configuration, the etching stop layer is formed of the conductive material. Thus, even if the positive ions in an etching gas enter a through part during the over etching in the through etching operation and collide with the etching stop layer, whereby the etching stop layer is positively charged, the positive charge of the etching stop layer is instantaneously neutralized electrically by the negative charge of the side wall surface of the through part.

[0034]

Thus, the etching stop layer is not continuously charged positively, preventing a conventional problem, i.e., a problem that the positive ions of the etching gas entered inside the through part during the over etching change their course immediately before reaching the etching stop layer by the continuous positively charged condition of the etching stop layer, and collide with the side wall surface of the through part in a curved manner, whereby notches are formed in the side wall surface of the through part on the side of the etching stop layer.

[0035]

In addition, since the etching stop layer formed of the conductive material has excellent heat conductivity, and the heat of the element substrate is easily transmitted through the etching stop layer thereof, avoiding the temperature of the area surrounded by the through part during the over etching from being higher than that of other areas. Thus, a problem of excessive etching that etching becomes excessive due to the temperature rise although a specified etching removal is completed, can be prevented.

[0036]

As described above, the sensor element can be manufactured with the dimensions as designed and with high

accuracy since the formation of notches in the side wall surface of the through part is avoided, and the excessive etching is prevented. Thus, the external force detection sensor having excellent performance can be easily provided.

[0037]

[Description of the Embodiments]

The embodiments of the present invention are described with reference to the drawings.

[0038]

Figs. 1(a) to 1(e) show a first embodiment of a method for manufacturing an external force detection sensor according to the present invention. In the explanation of the first embodiment, the same components as those in the above-described conventional example are indicated by the same numerals, and the duplicate explanation of common parts will be omitted.

[0039]

The first embodiment is characterized in that an etching stop layer 18 formed in manufacturing a sensor element 1 constituting the external force detection sensor is formed of an electrically conductive material. Other configurations are same as those in the conventional example.

[0040]

Recently, higher sensitivity has been demanded for

the external force detection sensor such as an angular velocity sensor, and it is desired to manufacture the sensor element 1 with higher dimensional accuracy. Thus, notches n formed on a side wall surface of a through part 20 and excessive etching have raised a serious problem as described above. As described above, the etching stop layer 18 has been formed of an insulating material from the viewpoint of facilitation in forming the layer and simplification of the manufacturing process, and there is no idea of forming the etching stop layer 18 of other materials. However, to solve the above-described problem, the inventor considered that the above-described etching stop layer 18 is formed of a conductive material.

[0041]

That is, in the first embodiment, as indicated in Fig. 1(a), a recessed part 16 is formed on a back face 3b of an element substrate 3 to form a membrane 17 of a specified thickness d (e.g., 70μm). Then, as shown in Fig. 1(b), the etching stop layer 18 is formed on a top face 16a (a back surface of the membrane 17) of the recessed part 16. In the first embodiment, as described above, the etching stop layer 18 is formed of a conductive material, and the etching stop layer 18 is formed on the top face 16a of the recessed part 16 by, for example, an electron beam evaporation method or the film deposition technology such

as sputtering. In the first embodiment, the conductive material for forming the etching stop layer 18 is not less than 1 in selection ratio (i.e., the ratio of the dry-etching rate of the element substrate 3 to the dry-etching rate of the etching stop layer 18) in order to surely serve the function as the etching stop layer.

[0042]

Next, as shown in Fig. 1(c), the support substrate 2 is arranged on the back surface 3b of the element substrate 3, and the support substrate 2 and the element substrate 3 are anode-coupled to each other. Then, as shown in Fig. 1(d), the through dry etching of the membrane 17 of the element substrate 3 is effected from the front face 3a making use of the photolithography and the dry-etching technology such as RIE to form a plurality of through parts 20 reaching the etching stop layer 18. The sensor element 1 as shown in Fig. 6 is formed by the plurality of through parts 20.

[0043]

During the through dry etching, at the through parts 20 under the over-etching operation, an etching gas enters inside the through parts 20, and the positive ions in the etching gas collide with the etching stop layer 18, and the etching stop layer 18 is positively charged. Since the etching stop layer 18 is formed of the conductive material,

the positive charge in the etching stop layer 18 is instantaneously and neutralized electrically by the negative charge on the side wall surface of the through parts 20 to eliminate the positively charged condition of the etching stop layer 18.

[0044]

Thus, in the through parts 20 under the over-etching operation, the positive ions in the etching gas entered inside go straight toward the etching stop layer 18, and collided with the etching stop layer 18, preventing a problem that the course of the positive ions is curved due to the etching stop layer 18 which is continuously charged positively, and collide with the side wall surface of the through parts 20 to form notches n in the side wall surface.

[0045]

In addition, in the first embodiment, since the etching stop layer 18 is formed of the conductive material and has excellent thermal conductivity as described above, and it can function as a heat transfer passage. Thus, even if a part surrounded by the through parts 20 under the over-etching operation generates heat by the collision of the etching gas, the heat is transferred to other areas through the etching stop layer 18, so that the temperature of approximately whole area to be etched can be set similar. Excessive etching due to non-uniform temperature can be

avoided thereby.

[0046]

As described above, both the notch n preventive effect of the side wall surface of the through parts 20 and the excessive etching avoiding effect due to the non-uniform temperature can be exhibited by forming the etching stop layer 18 of the conductive material. In particular, based on the experiment by the inventor, the above effects are remarkable and preferable when the conductive material having electric conductivity of not less than $1 \times 10^6\ \Omega^{-1}\cdot m^{-1}$ and heat conductivity of not less than 0.1W·cm-1·K^{-1} is used for the material for forming the above etching stop layer 18. For example, the etching stop layer 18 is optimally formed of titanium (electric conductivity of $1.7 \times 10^6\ \Omega^{-1}\cdot m^{-1}$ and heat conductivity of $0.219 W\cdot cm^{-1}\cdot K^{-1}$) and aluminum (electric conductivity of $3.8 \times 10^7\ \Omega^{-1}\cdot m^{-1}$ and heat conductivity of $2.37 W\cdot cm^{-1}\cdot K^{-1}$).

[0047]

Nickel or copper, etc. may be, of course, used for the conductive material of the etching stop layer 18. The thickness of the etching stop layer 18 is appropriately set in consideration of the type of the conductive material for forming the etching stop layer 18 and the thickness of the membrane 17, etc. For example, when the etching stop layer 18 is formed of titanium or aluminum, the etching stop

layer 18 is formed to have the thickness of approximately 300 nm in thickness.

[0048]

After the predetermined forming of all the through parts 20 is completed by the through dry etching, the etching stop layer 18 formed of the above conductive material is removed by wet etching as shown in Fig. 1(e) by means of, for example, hydrofluoric acid aqueous solution. The hydrofluoric acid aqueous solution removes the etching stop layer 18 of the electrically conductive material by wet etching, but does not damage the element substrate 3.

[0049]

As described above, after the etching stop layer 18 is removed by wet etching, a lid part 30 shown by a broken line in Fig. 1(e) as necessary. In this case, for example, a glass substrate serving as the lid part 30 with a recessed part 31 formed therein, is arranged on the front face of the element substrate 3 shown in Fig. 1(e), and the recessed part 31 of the glass substrate 30 is arranged opposite to the sensor element 1 of the element substrate 3, and the element substrate 3 is lapped on the glass substrate 30 so as to be anode-coupled to each other. When the lid part 30 is provided in this manner, the sensor element 1 is accumulated and sealed in an internal space formed by the support substrate 2 and the lid part 30. The

internal space may be evacuated according to the operational characteristic of the sensor element 1.

[0050]

In the first embodiment, the external force detection sensor is manufactured by the above manufacturing method.

[0051]

According to the first embodiment, since the etching stop layer 18 is formed of the electrically conductive material, the etching stop layer 18 at a bottom part of the through parts 20 under the over-etching operation can be prevented from being continuously charged positively during the through dry etching, and the formation of notches n in the side wall surface of the through parts 20 due to the continuous positive-charge of the etching stop layer 18 can be avoided. In addition, since the etching stop layer 18 formed of the conductive material can function as a heat transfer passage, the heat is transferred through the etching stop layer 18, and the temperature can be maintained approximately same over almost whole area to be etched, and the excessive etching due to the non-uniform temperature can be prevented.

[0052]

As described above, since both the formation of notches n and the excessive etching can be prevented, the sensor element 1 can be manufactured with high dimensional

accuracy, the external force detection sensor having excellent sensitivity and stable output sensitivity can be provided, and the reliability of the quality of the external force detection sensor can be improved.

[0053]

Further, in the first embodiment, since the etching stop layer 18 is formed of the conductive material in which the selection ratio is not less than 1, and there hardly arises a problem that the etching stop layer 18 is subjected to the etching removal during the through dry etching and holes are formed in the etching stop layer 18. Even if the holes are formed in the etching stop layer 18, the etching stop layer 18 is formed almost over the whole area of the top surface 16a of the recessed part 16 in this first embodiment, so that the top face 16a of the recessed part 16 can be prevented from being damaged by the etching gas entering inside the recessed part 16 from holes in the etching stop layer 18.

[0054]

As shown in the first embodiment, the etching stop layer 18 is formed of the conductive material, and thus various changes must be added to the conventional manufacturing process. Of course, the inventor considers an appropriate manufacturing process in a case where the etching stop layer 18 is formed of the conductive material,

but a detailed explanation thereof is omitted here.

[0055]

A second embodiment will be described below. In the explanation of the second embodiment, the same components as those in the above-described first embodiment are indicated by the same numerals, and the duplicate explanation of common parts will be omitted.

[0056]

Figs. 2(a) to 2(e) show the second embodiment of the method for manufacturing the external force detection sensor according to the present invention. In the second embodiment, firstly as shown in Fig. 2(a), an etching stop layer 18 is formed almost over the whole area of the back face 3b of an element substrate 3 by the film deposition technology such as sputtering. Also in this second embodiment, the etching stop layer 18 is formed of the conductive material similar to that in the above embodiment.

[0057]

As shown in Fig. 2(b), a dummy support substrate 25 is attached to the back face 3b of the element substrate 3 through the etching stop layer 18 and an adhesive layer (e.g., photo resist) 23.

[0058]

Thereafter, as shown in Fig. 2(c), a plurality of through parts 20 leading to the etching stop layer 18 from

the front face 3a of the element substrate 3 are formed by the through dry etching to form the sensor element 1 as shown in Fig. 6.

[0059]

A coupled body of the element substrate 3 with the dummy support substrate 25 is dipped in acetone solution, etc. to dissolve the adhesive layer 23, and the dummy support substrate 25 is separated from the element substrate 3. Then, as shown in Fig. 2(d), the etching stop layer 18 formed of the conductive material is removed by wet etching using an aqueous solution such as a hydrofluoric acid aqueous solution.

[0060]

Thereafter, as shown in Fig. 2(e), the glass support substrate 2 with a recessed part 26 formed therein is arranged on the back face 3b of the element substrate 3 to allow the recessed part 26 of the support substrate 2 to oppose to the sensor element 1 of the element substrate 3, and the support substrate 2 is anode-coupled to the element substrate 3. In this case, a lid part 30 shown in the first embodiment may be simultaneously anode-coupled to the front face of the element substrate 30, as necessary. The recessed part 26 of the support substrate 2 is provided not to prevent the sensor element 1 from being moved.

[0061]

Also in the second embodiment, the etching stop layer 18 is formed of the conductive material similar to that in the first embodiment, and thus, the etching stop layer 18 is prevented from being continuously charged positively, and the formation of notches n in the side wall surface of the through parts 20 can be avoided, and at the same time, non-uniform temperature in the area to be etched can be prevented, and the excessive etching due to the non-uniform temperature can be avoided. Thus, the sensor element 1 can be manufactured with high dimensional accuracy, and the external force detection sensor having excellent sensitivity and stable output sensitivity can be provided.

[0062]

A third embodiment will be described below. In the explanation of the third embodiment, the same components as those in the above embodiments are indicated by the same numerals, and the duplicate explanation of common parts will be omitted.

[0063]

Figs. 3(a) to 3(d) show the third embodiment of the method for manufacturing the external force detection sensor. In the third embodiment, firstly as shown in Fig. 3(a), the etching stop layer 18 is formed in a set sensor element forming area R (i.e., an area for forming the sensor element 1 shown in Fig. 6) on the back face 3b of

the semiconductor element substrate 3. Also in the third embodiment, the etching stop layer 18 is formed of the conductive material similar to that in the above embodiments, and the etching stop layer 18 is formed on the back face 3b of the element substrate 3 by the electron beam evaporation method and the film deposition technology such as sputtering similar to the above embodiments.

[0064]

As shown in Fig. 3(b), a glass support substrate 2 with a recessed part 26 formed therein is arranged on the back face 3b of the element substrate 3 to allow the recessed part 26 of the support substrate 2 to oppose to the etching stop layer 18 of the element substrate 3, and the support substrate 2 is anode-coupled to the element substrate 3.

[0065]

Thereafter, as shown in Fig. 3(c), the sensor element forming area R is worked from the front face 3a of the element substrate 3 by the through dry etching to form a plurality of through parts 20 leading to the etching stop layer 18, and the sensor element 1 as shown in Fig. 6 is formed. Next, as shown in Fig. 3(d), the etching stop layer 18 is removed by the method similar to that in the above embodiments. Then, the lid part 30 described in the first embodiment may be anode-coupled to the front face of

the element substrate 30, as necessary. The external force detection sensor is thus manufactured.

[0066]

Also in the third embodiment, since the etching stop layer 18 is formed of the conductive material similar to the above embodiments, both the formation of notches n in the side wall surface of the through parts 20 and the excessive etching can be avoided, so that the sensor element 1 can be formed in the designed dimensions. Thus, it is possible to provide the external force detection sensor having excellent sensitivity and stable output sensitivity.

[0067]

A fourth embodiment will be described below. In the explanation of the fourth embodiment, the same components as those in the above embodiments are indicated by the same numerals, and the duplicate explanation of common parts will be omitted.

[0068]

Figs. 4(a) to 4(e) show the fourth embodiment of the method for manufacturing the external force detection sensor. In the fourth embodiment, the external force detection sensor is manufactured by the manufacturing processes approximately similar to those of the third embodiment, but the fourth embodiment is differently

characterized in that a glass support substrate 2 is anode-coupled to the semiconductor element substrate 3 as shown in Fig. 4(b), and then, the thickness of the element substrate 3 is reduced by etching or cutting to the predetermined value, as shown in Fig. 4(c) and thereafter, a plurality of through parts 20 are formed in the element substrate 3 by the through dry etching to form a sensor element 1.

[0069]

According to the fourth embodiment, since the etching stop layer 18 is formed of the conductive material similar to the above embodiments, both the formation of notches n in the side wall surface of the through parts 20 and the excessive etching can be avoided, the sensor element 1 can be formed with high dimensional accuracy, and the external force detection sensor having excellent sensitivity and stable output sensitivity can be provided.

[0070]

Incidentally, when the thin-worked element substrate 3 is handled in a single body condition in manufacturing the external force detection sensor, the thin single element substrate 3 is easily broken, such as being cracked or partly chipped. To cope with this, in the fourth embodiment, the support substrate 2 is joined with the element substrate 3 before the element substrate 3 is

worked thin, and then, the element substrate 3 is formed thin. Thus, the thin element substrate 3 is not carried in a single body condition, and breakage of the element substrate 3 during the manufacture can be prevented. Further, a very precise carrying device may not be used to manufacture the external force detection sensor.

[0071]

A fifth embodiment will be described below. In the explanation of the fifth embodiment, the same components as those in the above embodiments are indicated by the same numerals, and the duplicate explanation of common parts will be omitted.

[0072]

Figs. 5(a) to 5(e) show the fifth embodiment of the method for manufacturing the external force detection sensor. In the fifth embodiment, firstly, as shown in Fig. 5(a), recessed parts 27 and 28 are formed in a set sensor element forming area R on both the front face 3a and the back face 3b of the semiconductor element substrate 3 to form the membrane 17.

[0073]

Next, as shown in Fig. 5(b), the etching stop layer 18 is formed on the back face of the membrane 17. Also in the fifth embodiment, the etching stop layer 18 is formed of the conductive material similar to the above embodiments.

[0074]

Thereafter, the glass support substrate 2 is anode-coupled to the back face 3b of the element substrate 3 as shown in Fig. 5(c), and as shown in Fig. 5(d), a plurality of through parts 20 are formed by through dry etching of the membrane 17 from the front face to form the sensor element 1 as shown in Fig. 6. Then, as shown in Fig. 5(e), the etching stop layer 18 is removed by the method similar to that in the above embodiments to form the sensor element 1. Then, the lid part 30 may be provided on the front face of the element substrate 3 similar to the above embodiments. The external force detection sensor can be manufactured as described above.

[0075]

Also in the fifth embodiment, the etching stop layer 18 is formed of the conductive material similar to the above embodiments, and thus, both the formation of notches n in the side wall surface of the through parts 20 and the excessive etching can be avoided, whereby the sensor element 1 can be formed in the designed dimensions, and the sensitivity and the stability in the output sensitivity of the external force detection sensor can be improved.

[0076]

The present invention is not limited to the above embodiments, but various embodiments can be adopted. For

example, in the above embodiments, the element substrate 3 is not cooled during the dry etching, but the element substrate 3 may be cooled during the dry etching. When the etching stop layer 18 is formed of the insulating material like a conventional practice, the above problem of non-uniform temperature is raised even if the whole element substrate 3 is cooled during the through dry etching. In contrast, by forming the etching stop layer 18 of the conductive material similar to the above embodiments, an effect similar to that in the above embodiments can be obtained even if the element substrate 3 is cooled during the through dry etching.

[0077]

In addition, in the second embodiment, the element substrate 3 is joined with the dummy support substrate 25 through the etching stop layer 18 and the adhesive layer 23, but when the etching stop layer 18 is formed of a conductive adhesive such as a conductive resin, the etching stop layer 18 can function as the adhesive layer, and the adhesive layer 23 may be omitted.

[0078]

Further, although the support substrate 2 is formed of a glass material in the above respective embodiments,, the support substrate 2 may be formed of a silicon substrate, and a material for forming the support substrate

2 is not limited.

[0079]

Further, although the etching stop layer 18 is formed of the electrically conductive material whose selection ratio is not less than 1 in the above embodiments, it may be formed of the conductive material whose etch selectivity is less than 1 when the thickness of the etching stop layer 18 is increased.

[0080]

Further, although explanation is given with the angular velocity sensor shown in Fig. 6 as an example in the above embodiments, the present invention is, of course, applicable to various external force detection sensors other than the angular velocity sensor shown in Fig. 6, such as an acceleration sensor.

[0081]

[Advantages]

According to the present invention, since the etching stop layer is formed of the conductive material, even if the positive ions in the etching gas entering inside the through parts under the over-etching operation collide with the etching stop layer to charge positively the etching stop layer while the through parts are formed in the element substrate by through dry etching, the positive charge in the etching stop layer is instantaneously and

electrically neutralized by the negative charge on the side wall surface of the through parts, and the positively charged condition of the etching stop layer is eliminated and not continuous.

[0082]

Therefore, almost all positive ions in the etching gas entering inside the through parts under the over-etching operation go straight toward the etching stop layer, and are prevented from colliding with the side wall surface of the through parts. By virtue of this, the formation of notches in the side wall surface of the through parts can be avoided.

[0083]

In addition, since the etching stop layer is formed of the electrically conductive material and has good heat conductivity, the etching stop layer can function as the heat transfer passage, and the temperature of area to be etched can be set uniform almost over the whole area during through etching, and the excessive etching due to the non-uniform temperature can be prevented.

[0084]

As described above, by forming the etching stop layer of the conductive material, it is possible to avoid both the formation of notches in the side wall surface of the through parts and the excessive etching. By virtue of this,

the sensor element can be manufactured as designed with high dimensional accuracy. Therefore, the external force detection sensor having excellent sensitivity, stable output sensitivity and high reliability of quality can be provided.

[0085]

In a method for manufacturing the external force detection sensor in which the recessed part is provided in the back face of the element substrate to form the membrane, and the membrane is worked by through dry etching to form the sensor element, in a method for manufacturing an external force detection sensor in which the dummy support substrate is joined with the element substrate, and the element substrate is worked by through dry etching to form the sensor element, in a method for manufacturing an external force detection sensor in which the etching stop layer is formed in the set sensor element forming area on the back face of the element substrate, the support substrate with the recessed part formed therein is joined with the element substrate, and the membrane is worked by the through dry etching to form the sensor element, or in a method for manufacturing an external force detection sensor in which the recessed part is formed on both the front face and back face of the element substrate to form the membrane, and the membrane is worked by through dry etching to form

the sensor element, the sensor element is very fine in size, and it is not easy to form the sensor element with high dimensional accuracy. However, by using the present invention, it becomes easy to manufacture the sensor element as designed with high dimensional accuracy, even if the sensor element is very fine, and the sensor element is very effective for manufacturing the external force detection sensor having a small size and excellent performance.

[0086]

In a method for manufacturing the external force detection sensor in which the etching stop layer is formed in the set sensor element forming area on the back face of the element substrate, the support substrate with the recessed part formed therein is joined with the element substrate and then, the element substrate is worked thin to the predetermined thickness, and the membrane is worked by the through dry etching to form the sensor element, the thin element substrate can be protected by the support substrate during the manufacture, the breakage of the element substrate can be prevented, and the yield of the external force detection sensor can be improved.

[0087]

In a manufacturing method in which the element substrate is formed of silicon, the support substrate is

formed of a glass material, and the element substrate is anode-coupled to the support substrate, the element substrate can be firmly joined with the support substrate to improve the mechanical reliability of the external force detection sensor.

[0088]

In addition, when the sensor element is a movable element, more specific dimensional accuracy is required. However, by employing the present invention, the exact request can be sufficiently coped with. It is possible to manufacture the sensor element which is the movable element having excellent characteristic, and the external force detection sensor having excellent sensitivity and stable output sensitivity can be provided.

[0089]

Further, when the etching stop layer is formed of the conductive material having a selection ratio, which is the ratio of the dry-etching rate of the element substrate to the dry-etching rate of the etching stop layer, of not less than 1, a condition that holes are formed in the etching stop layer is during dry etching can securely be avoided.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 includes views showing a first embodiment of a method for manufacturing an external force detection sensor

according to the present invention.

[Fig. 2]

Fig. 2 includes explanatory views showing a second embodiment.

[Fig. 3]

Fig. 3 includes explanatory views showing a third embodiment.

[Fig. 4]

Fig. 4 includes explanatory views showing a fourth embodiment.

[Fig. 5]

Fig. 5 includes explanatory views showing a fifth embodiment.

[Fig. 6]

Fig. 6 is an explanatory view showing an example of the external force detection sensor.

[Fig. 7]

Fig. 7 includes explanatory views showing an example of a conventional method for manufacturing the external force detection sensor.

[Fig. 8]

Fig. 8 is a view for illustrating conventional problems.

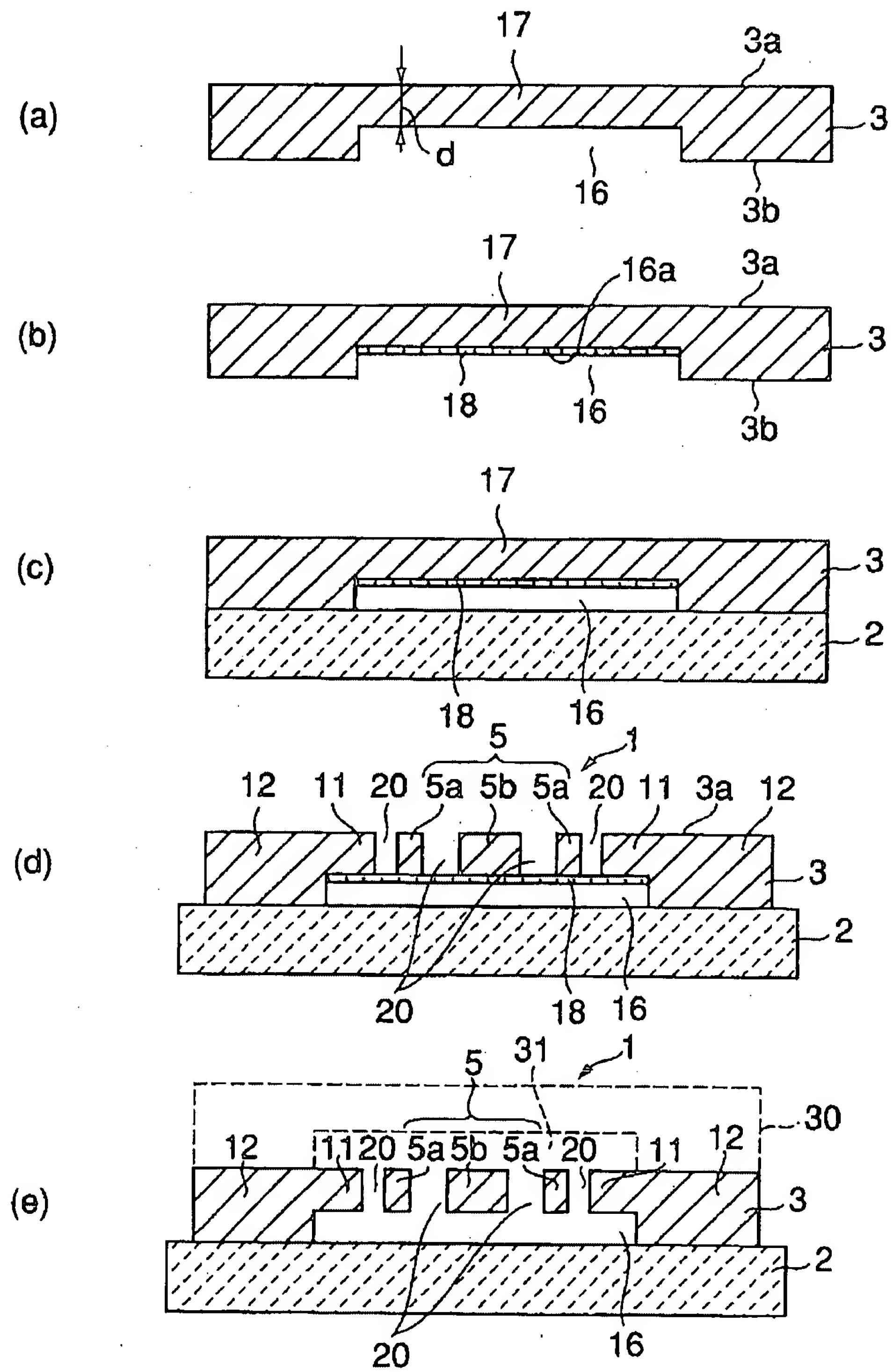
[Reference Numerals]

1 sensor element

2	support substrate
3	element substrate
5	vibrator
16	recessed part
16a	top face of the recessed part
17	membrane
20	through part
25	dummy support substrate

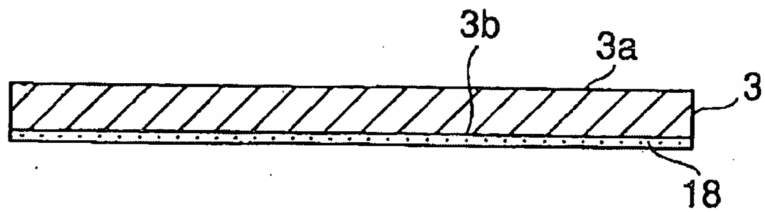
【書類名】 図面 [Name of Document] DRAWINGS

【図１】 [FIG. 1]



【図２】 [FIG. 2]

(a)



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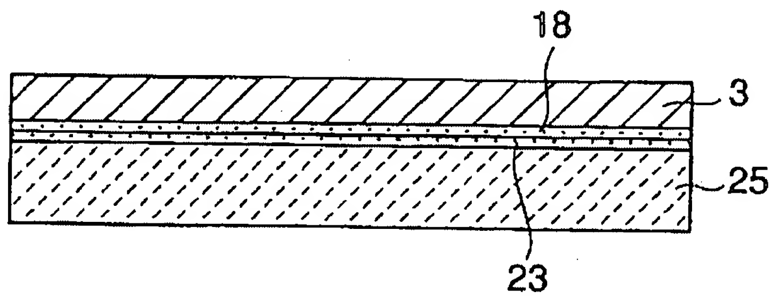

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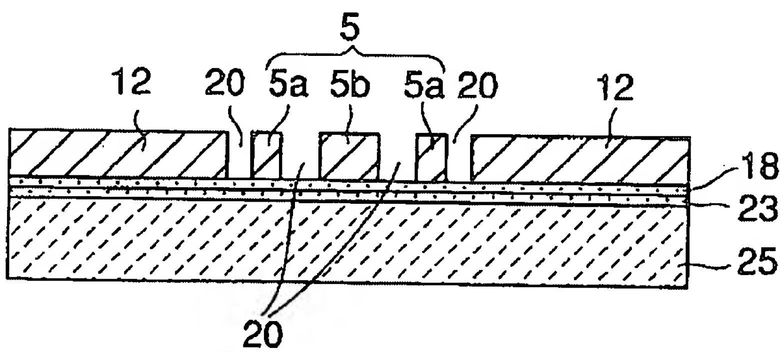

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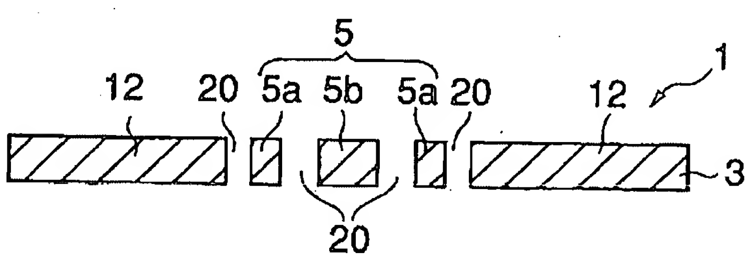
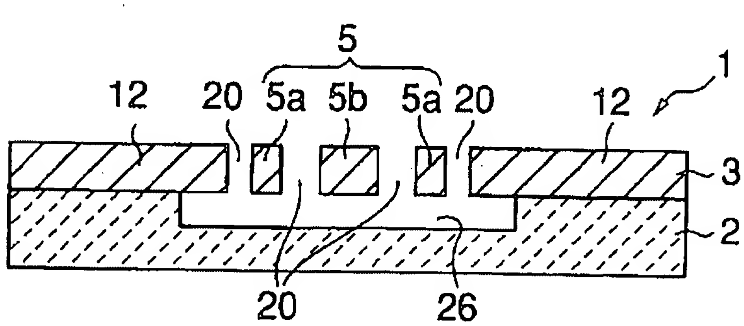


(e)



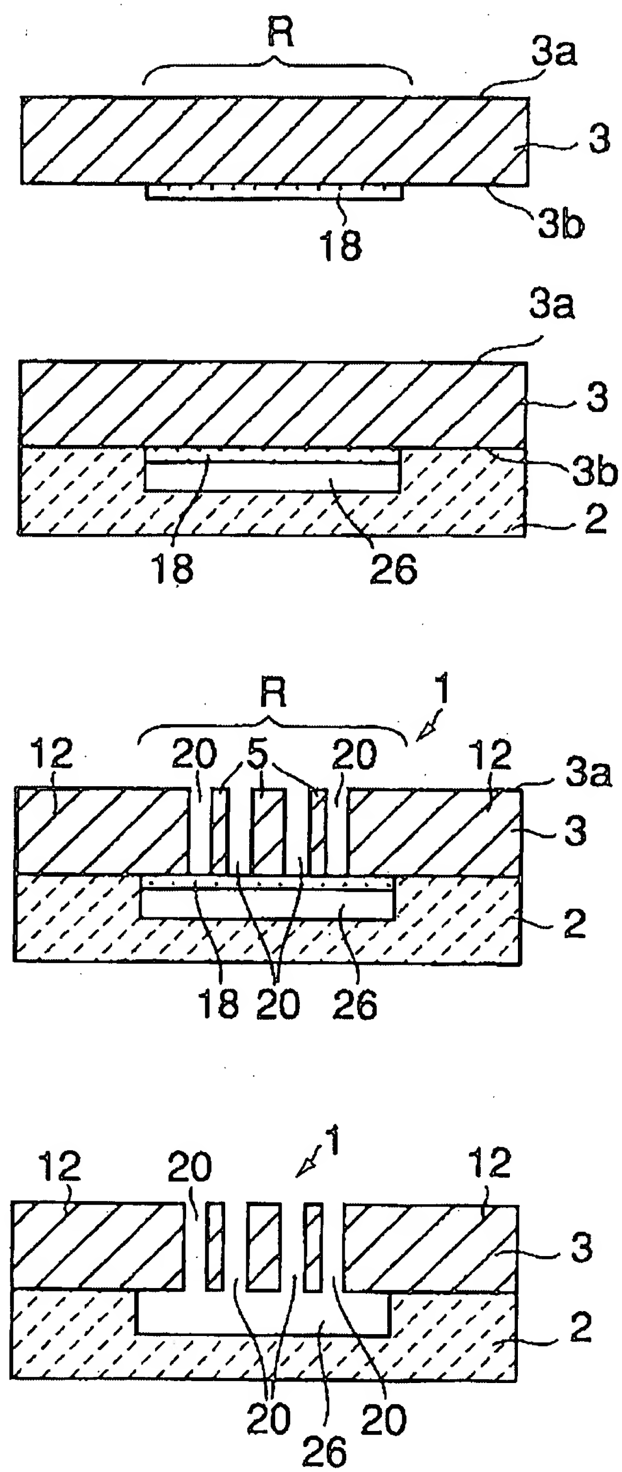
【図３】 [FIG. 3]

(a)

(b)

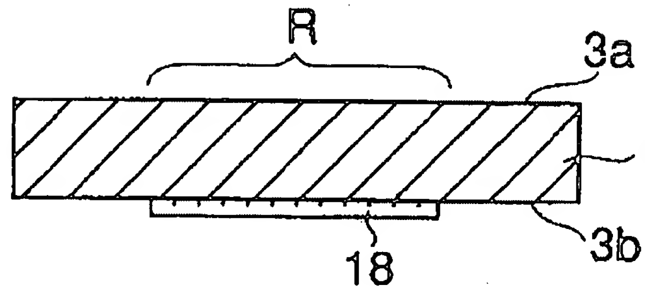
(c)

(d)


R
3a
3
3b
18
3a
3
3b
2
18
26
R
1
12
20
5
20
12
3a
3
2
18
20
26
12
20
1
12
3
2
20
26
20

【図４】 [FIG. 4]

(a)



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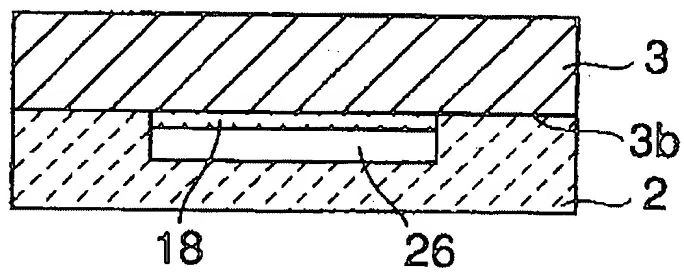

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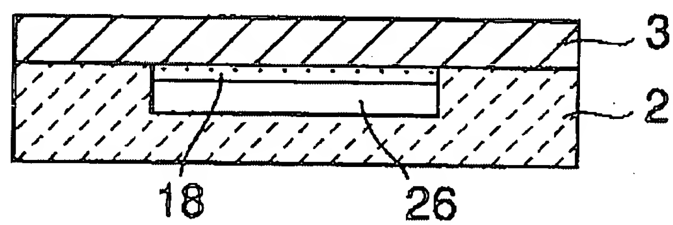

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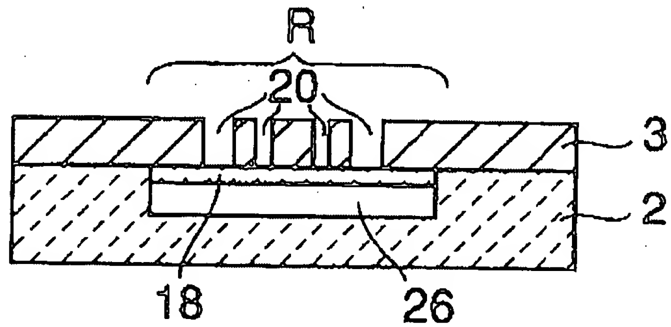

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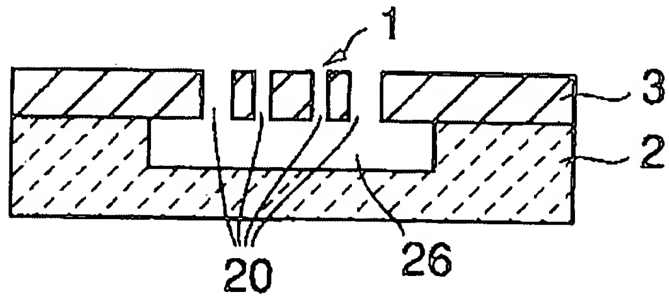
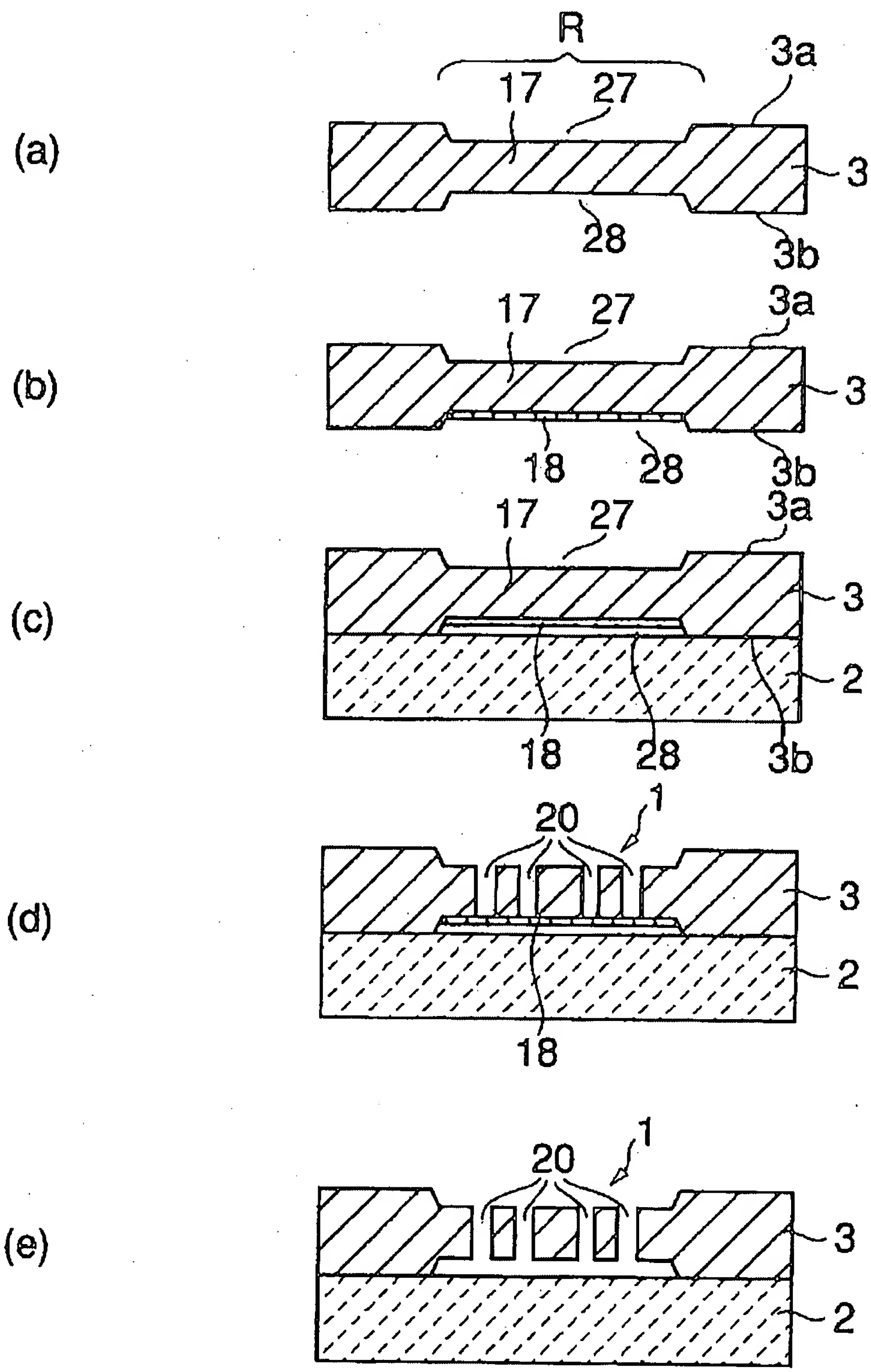
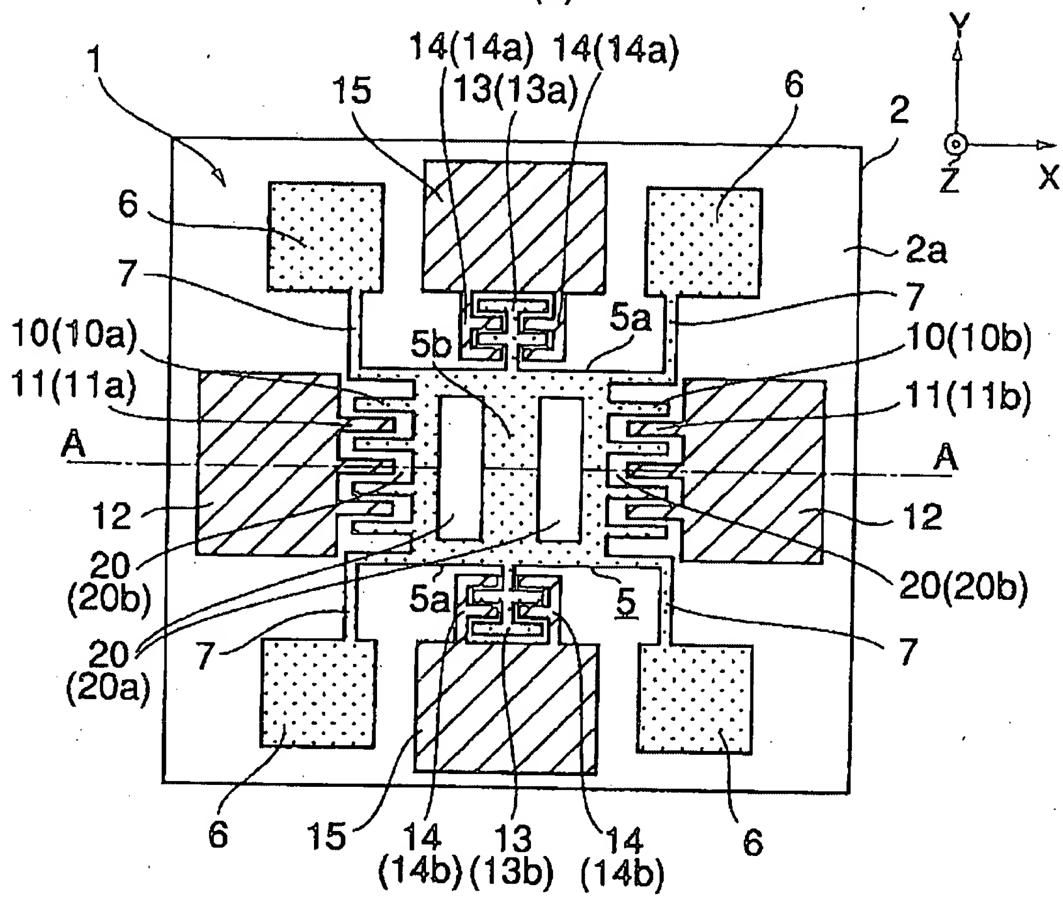


【図5】 [FIG. 5]


(a)
R
17
27
3a
3
28
3b
(b)
17
27
3a
3
18
28
3b
(c)
17
27
3a
3
2
18
28
3b
(d)
20
1
3
2
18
(e)
20
1
3
2

【図６】 [FIG. 6]

(a)


1
2
2a
6
7
15
14(14a) 14(14a)
13(13a)
5a
5b
10(10a)
11(11a)
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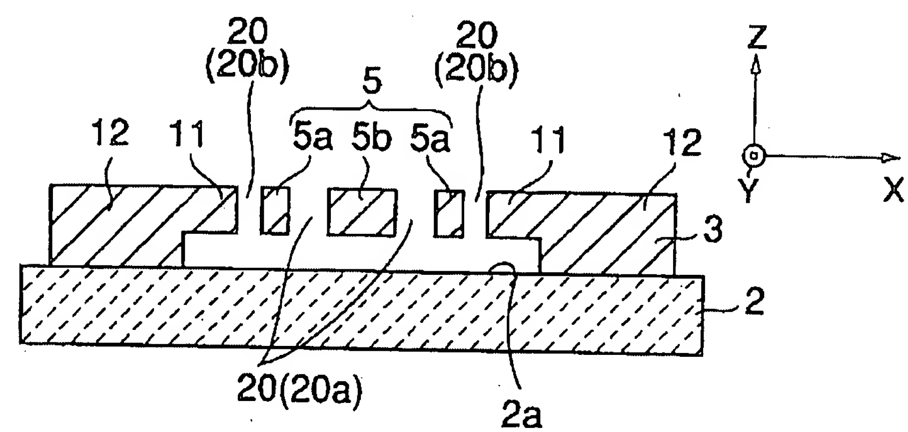
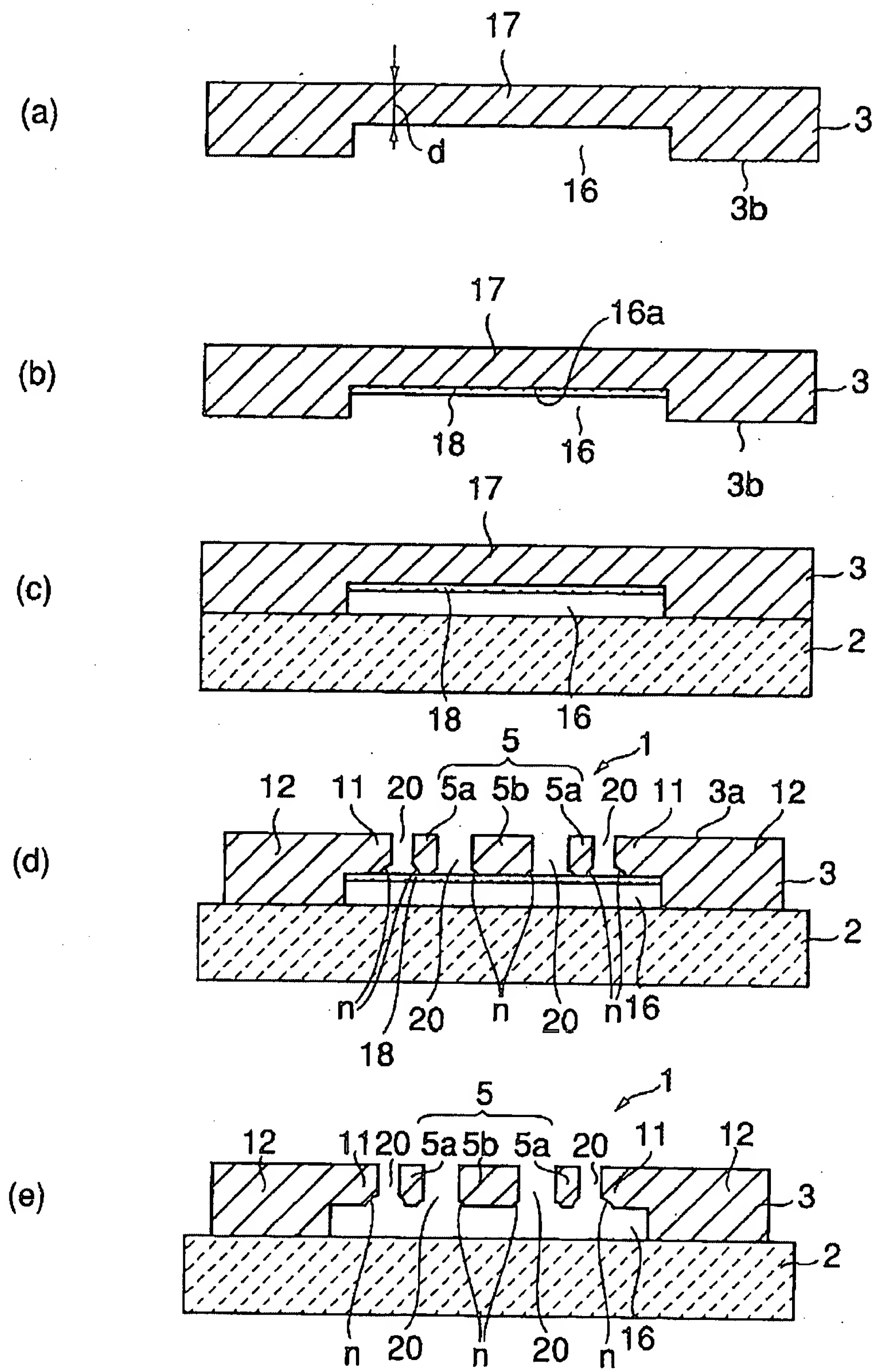
11(11b)
A
A
12
12
20
(20b)
20(20b)
20
(20a)
5a
5
7
7
6
6
15
14
(14b)
13
(13b)
14
(14b)
Y
Z
X

(b)


20
(20b)
20
(20b)
5
5a 5b 5a
12
11
11
12
3
2
20(20a)
2a
Z
Y
X

【図７】 [FIG. 7]


(a)
17
3
d
16
3b
(b)
17
16a
3
18
16
3b
(c)
17
3
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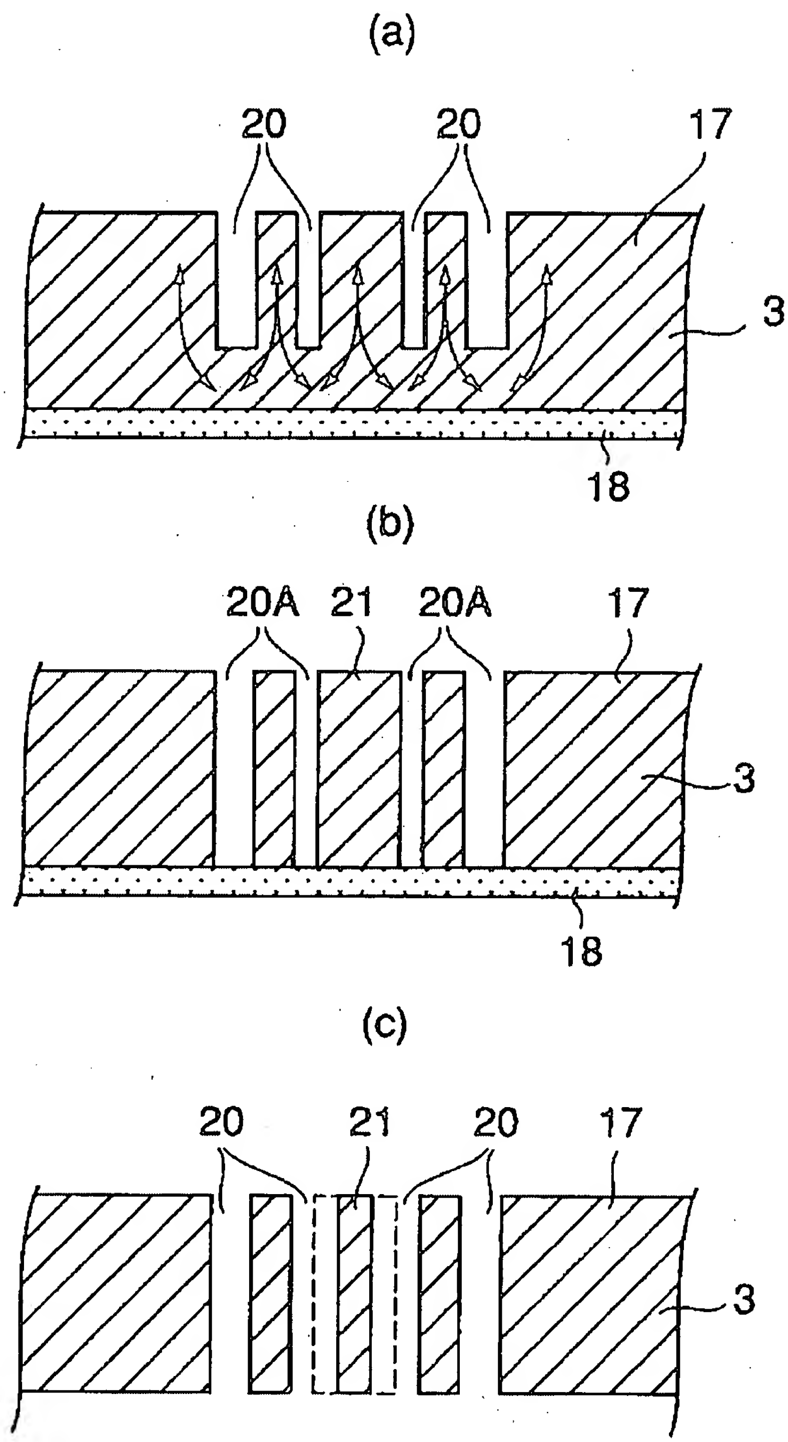
18
16
(d)
5
1
12
11
20
5a
5b
5a
20
11
3a
12
3
2
n
20
n
20
n16
18
(e)
5
1
12
11
20
5a
5b
5a
20
11
12
3
2
n
20
n
20
n
16

【図 8】 [FIG. 8]



JP Application No. 2000-026139

[Name of Document] ABSTRACT

[Abstract]

[Object] To form a sensor element of an external force detection sensor with high dimensional accuracy.

[Solving Means] A recessed part 16 is formed on a back face 3b of an element substrate 3 to form a membrane 17. Next, an etching stop layer 18 formed of a conductive material is formed on a top face 16a of the recessed part 16. After the silicon element substrate 3 is anode-coupled to a glass support substrate 2, a plurality of through parts 20 leading from a front face 3a of the element substrate 3 to the etching stop layer 18 are formed by dry etching to form a sensor element 1. Thereafter, the etching stop layer 18 is removed by wet etching with a hydrofluoric acid aqueous solution. The etching stop layer 18 composed of the conductive material prevents notches from being formed in a side wall surface of the through holes 20, and also prevents the excessive etching. By virtue of this, the sensor element 1 can be manufactured as designed with high dimensional accuracy, and an external force detection sensor having excellent stability of the output sensitivity can be provided.

[Selected Figure] Fig. 1